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Antenna-Plasma Coupling in the Range of Ion Cyclotron Resonance Frequency for Aditya Tokamak

M. S. GUPTA[1], R. A. SIDDIQUI[1], and APARNABORKAR[2]

[1]Department of Mathematics & IT,
Govt. N.P.G. College of Science, Raipur-492010, C.G., INDIA.
[2]Columbia Institute of Engineering & Technology,
BurkoniTekari (Village), Near Vidhan Sabha, INDIA.

ABSTRACT

Plasma is a hot ionized gas consisting of approximately equal numbers of positively charged ions and negatively charged electrons. The characteristics of plasmas are significantly different from those of ordinary neutral gases so that plasmas are considered as a "fourth state of matter." For creating and confining such hot ionized gas we need a device known as torodial device. Tokamak is the toroidal device, in which plasma is being confined with the help of principal magnetic field i.e known as toroidalmaganetic field and to have an equilibrium in which the plasma pressure is balanced by magnetic forces, for it another magnetic field is necessary i.e. known as poloidal magnetic field.

Keywords: Antenna-Plasma Coupling, Ion Cyclotron Resonance Frequency, Aditya Tokamak.

1. INTRODUCTION

The plasma current is produced by transformer action. A current is passed through primary coils around the torus. That gives a flux change through the torus and produces a toroidal electric field, which drives the plasma current. The plasma shape and position are controlled by the additional toroidal currents. The tokamak plasma have particle densities of around 10^{20} m^{-3}, which is 10^5 - 10^6 times lower than the atmosphere.

The wave launch from the plasma edge, get coupled to the plasma, travel with minimum losses up to core and deposit the power at requited position in the plasma. For deposit of power in the plasma, we use radio frequency heating technique. The Radio frequency heating falls into four major frequency ranges out of which, ion cyclotron resonance heating frequencies is being generally used to heat the plasma. In the ion cyclotron range of frequency high power is available at reasonably low cost, conventional transmission lines can be used to carry power to the plasma, simple antenna

be used to couple the power to the plasma[1].

Antenna-Plasma coupling play an important role in the range of ion cyclotron resonance frequency. For coupling we need dispersion relation as well as antenna-plasma coupling range.

2. THEORY

For the theoretical derivation we have considered the following basic equations in SI units for α- species (electrons, ions, helium).

The equation of motion,

$$m_\alpha n_\alpha \partial V_\alpha/\partial t = q_\alpha n_\alpha [E + V_\alpha \times B] \quad (2.1)$$

The current density, $J = \sum_\alpha n_\alpha q_\alpha V_\alpha$ (2.2)

Maxwell's equations,

$$\nabla\times E = -\partial B/\partial t \quad (2.3)$$

and $\nabla\times B = \mu_o J + (1/c^2)\,\partial E/\partial t$ (2.4)

The dielectric displacement vector,

$$D = \underline{K} . E = E + \iota/(\in_o\omega) J \quad (2.5)$$

where

m_α= mass of the α- species,

V_α= velocity of the α - species ,

q_α= charge of the α - species,

n_α= number density of α - species

B = resultant magnetic field,

E = electric field

k = propagation vector in x-y-z plane,

B_p = poloidal magnetic field in x-y plane

B_T= toroidal magnetic field along z-axis,

$x = \rho\cos\psi$, $y = \rho\sin\psi$, $z = z$, ρ= unit radii,

ψ = angle in x-y plane from x-axis

thus ,

$$B = B_p(\rho)\cos\psi e_x + B_p(\rho)\sin\psi e_y + B_T e_z \quad (2.6)$$

since we know that,

$$n\times(n\times E) + D = 0 \quad (2.7)$$

where, The refractive index (a dimensionless vector),

$$n = ck/\omega \quad (2.8)$$

Again introducing the term arising from finite temperature modification

$$\tau = \sum_\alpha [3\omega_{p\alpha}^2 T_\alpha/\{m_\alpha(\omega^2 - 4\omega_{c\alpha}^2)(\omega^2 - \omega_{c\alpha}^2)\}]^{[2]} \quad (2.9)$$

Where $T = -\tau\omega^2/c^2$ (2.10)

$\omega_{p\alpha}^2 = n_o q_\alpha^2/(\in_0 m_\alpha)$; (plasma frequency of α - species) (2.11)

$\omega_{c\alpha} = q_\alpha B/m_\alpha$; (cyclotron frequency of α - species) (2.12)

3. CONCLUSIONS

Antenna plasma coupling provides the components in the following range:

By using above equations we find dispersion relation, which help us in antenna -plasma coupling;

A. The electromagnetic field in the plasma i.e. ($\xi \le 0$)[3,4].

B. The electromagnetic field in the region between the plasma and the antenna.

C. The electromagnetic field in the region between the antenna and the vessel wall.

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